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The penile bone and anterior process of the rat in scanning electron microscopy

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INTRODUCTION

The role of the penile bone is made puzzling by its absence in some species and its variable form in others (Burt, 1960). For example, rodents often have one or more cartilaginous processes lying distally between the bone and the tip of the glans. Gilbert (1892) postulated that the bone and any accessory cartilages aid penetration, contribute to rigidity, heighten sensation, and help the glans to plug the vagina long enough for a coagulating plug to set. Evidence for any role, other than changing rigidity, is scant.

The scanning electron microscopy of the rat's penile bone, in this report, seeks to answer these queries. How do its surfaces compare with those of other bones (Boyde, 1972), in particular at the base where cartilage is present during growth? How is the bone related to other penile tissues, including the partly bony anterior cartilaginous process? What are the patterns of resorption and deposition in growth and maturity? What does the bone do?

MATERIAL AND METHODS

The distal penes of Sprague–Dawley rats, five aged 8 weeks and twenty at 1 year, were dissected to remove the penile bone, still enclosed in periosteum and bound firmly to the anterior process. Part of the base of some bones was sawn off to expose the marrow cavity. The bones and processes were made anorganic by placing them in a 5 % solution of sodium hypochlorite (Boyde & Hobdell, 1969) for 8 hours at 4 °C, with occasional vigorous squirting of the solution at the bone. The bone, and now separate anterior process, were squirt-washed in four changes of distilled water, air-dried at 45 °C, glued to stubs and coated by evaporation with approximately 20 nm of carbon and 30 nm of gold, or sputter-coated with 20 nm of gold. Specimens were viewed in an ETEC microscope at 20 kV.

RESULTS

The mature bone has a roughly cylindrical shaft (Fig. 1) extending from a much broader base, and is flattened on its dorsal and ventral aspects. The tip (distal end) of the bone is bevelled to fit under the proximal end of the anterior process, the matching mineralized surface being also bevelled (Fig. 2) and somewhat concave (Fig. 1).

The anterior process in the young animal is fibrocartilaginous, and at 8 weeks does not survive the anorganic treatment. By one year it is extensively replaced by irregu-

Fig. 1. Lateral and slightly posterior view of a penile bone and the anterior process (*A*). The tip of the cylindrical shaft is bevelled to fit under the bevelled concavity of the process. (All figures are from anorganic preparations, and all except Figs. 8 and 9 are from mature bones.) × 30.

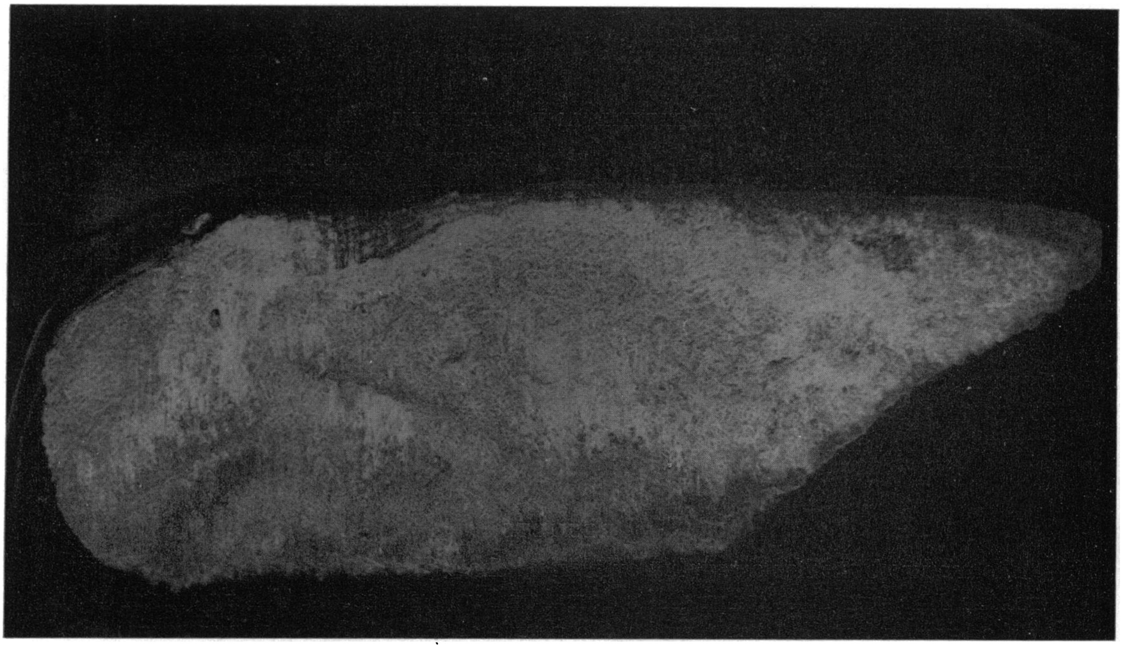

Fig. 2. Lateral view of anterior process showing the proximal bevel in profile, and its very irregular surface. × 70.

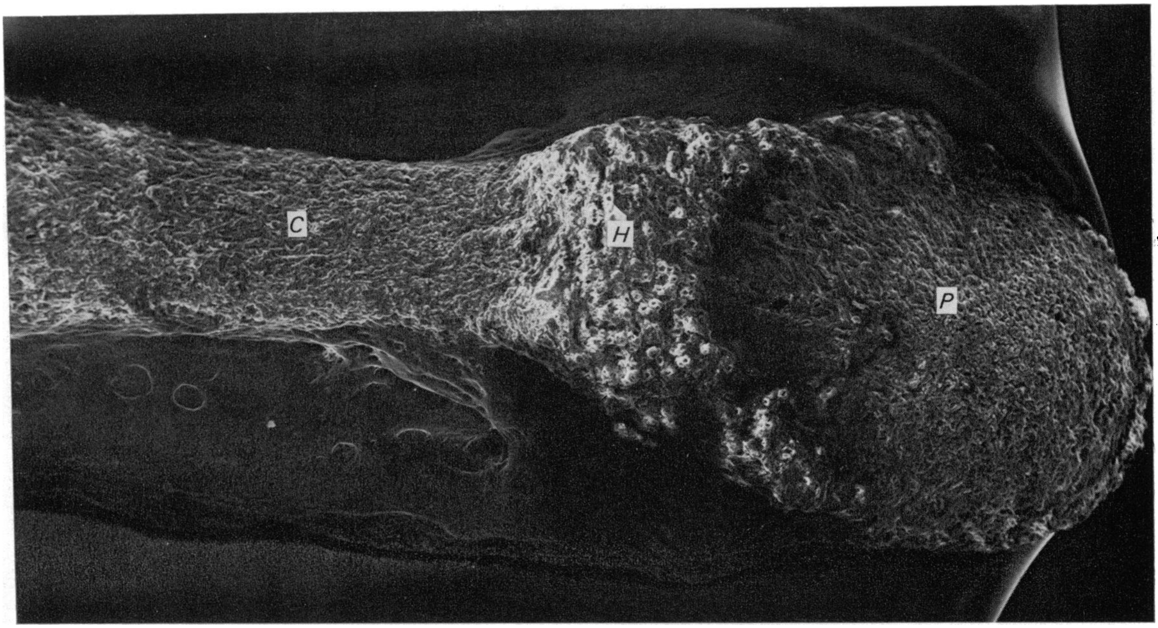

Fig. 3. Dorsal and slightly lateral view of the distal end of the penile bone. The flat, bevelled sole plate (*P*) and dorsal crest (*C*) are Sharpey-fibre bone, separated by a hump (*H*) with protruding open-topped, domed lacunae. The lateral surface of the shaft is smooth, resting bone. ×90.

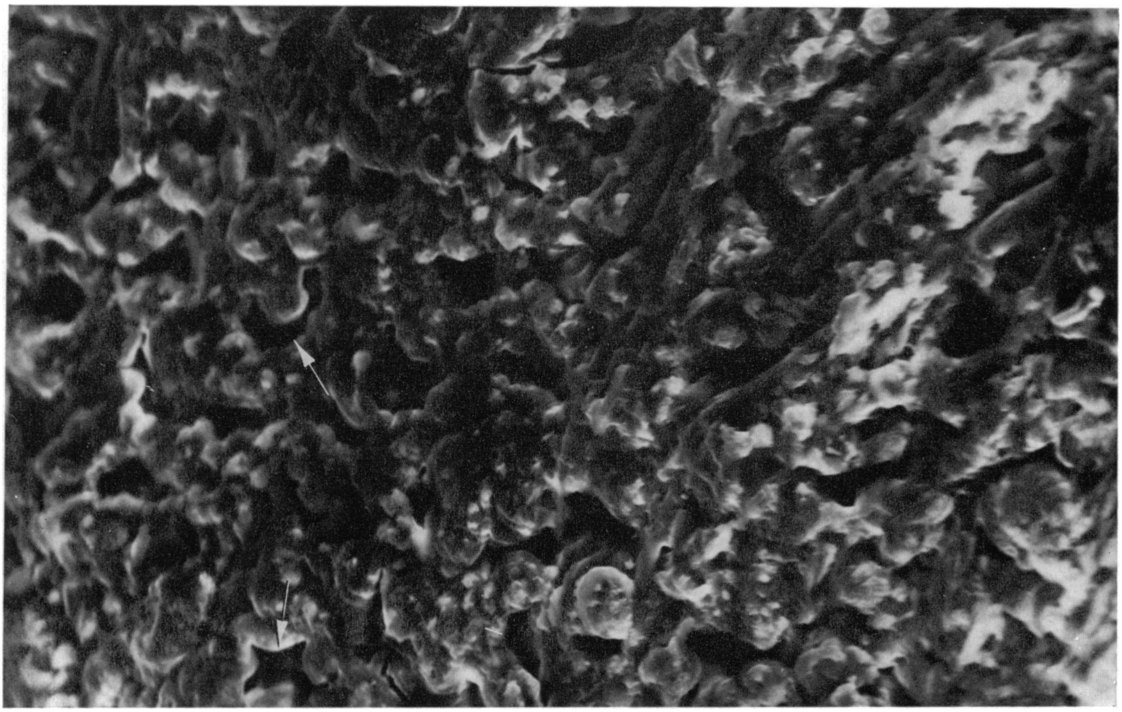

Fig. 4. View of the central sole plate of the specimen shown in Fig. 3. The surface is irregular, with many elevated mineralized Sharpey-fibres around osteoblast lacunae (arrow). ×900.

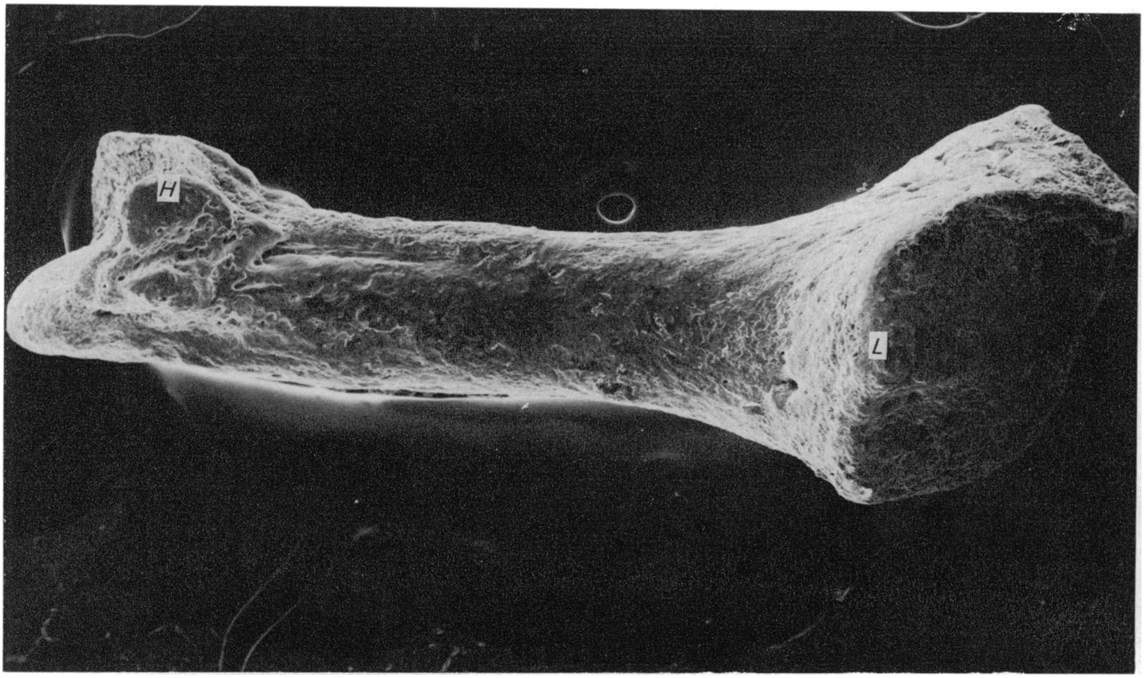

Fig. 5. Lateral view of a bone showing an accentuated, dorsal, distal hump (*H*). The shaft side is smoother, with some dark, amorphous patches. A lip (*L*) extends around the base, back and down into a dorsal depression. ×40.

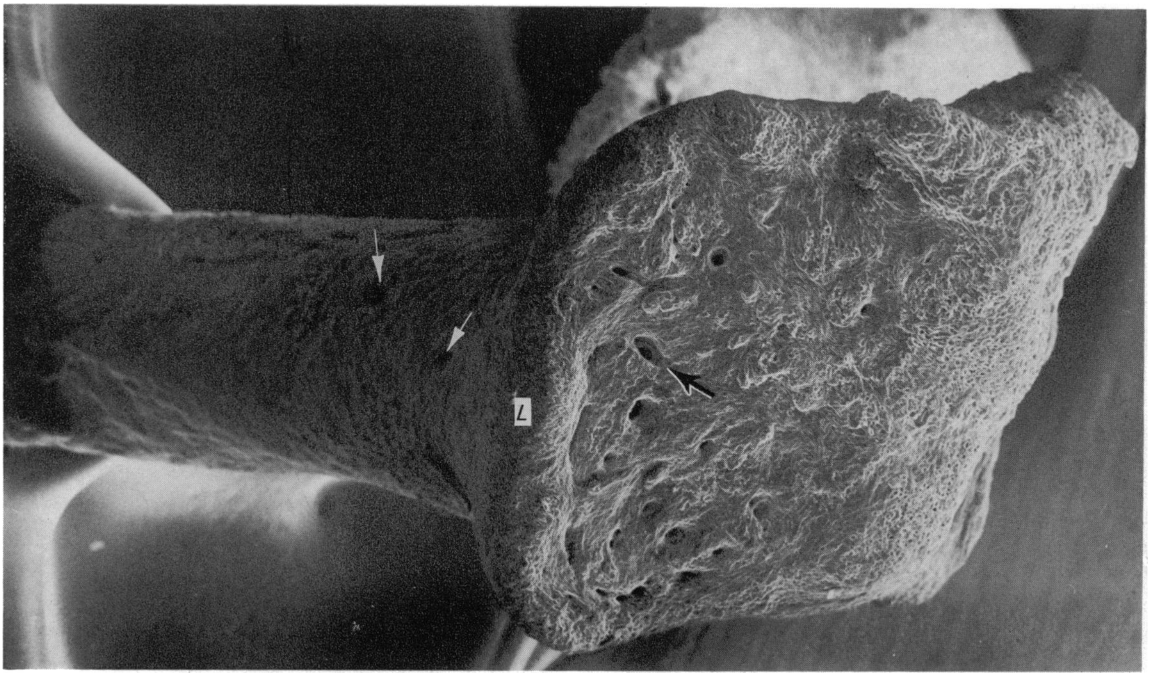

Fig. 6. Lateral and slightly posterior view of a bone showing two small vascular canals in the shaft (arrows) and others in the base. One basal canal (thick arrow) is seen in Fig. 7. The base has a lip (*L*) around it and is very uneven. ×60.

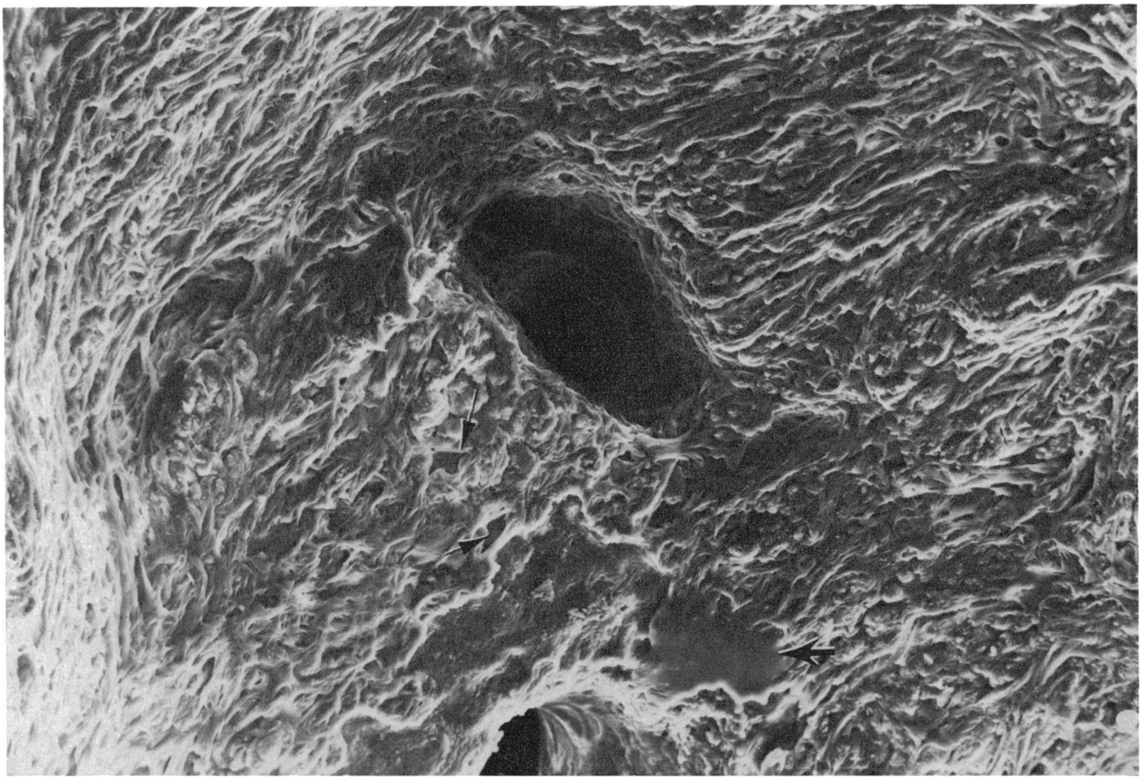

Fig. 7. View around the vascular canal of Fig. 6. Thick mineralized fibres run mostly in interwoven fashion over the surface, but some project as small, smooth mounds. The texture contrasts with the smoother bone lining the canals, and over the amorphous patch (thick arrow). Two osteoblast lacunae are arrowed. ×350.

lar endochondral bone. Its unmineralized, collagenous outer surface, with its fastening to the penile bone, is lost in the anorganic treatment, but the shape of the hard tissue remains approximately that of the intact anterior process. Its very rough mineralized surface emits many secondary electrons during scanning electron microscopy, making it appear brighter than the penile bone (Fig. 1).

On the dorsal side of the penile bone (Fig. 3) there is a crest which runs along the shaft, becoming more prominent as it approaches the flatter, bevelled region of the tip that lies like a 'sole plate' under the anterior process. The sole plate surface (Fig. 4) has many osteoblast lacunae contorted to fit between irregular small projections composed of thick mineralized Sharpey's fibres (Sharpey-fibre bone). The dorsal crest bone is similar (Fig. 3), except that more of the mineralized fibres run tangentially rather than at right angles into the deeper bone.

Between the crest and the sole plate there is an elevated region (Fig. 3), occasionally very protrusive (Fig. 5), where some open-topped domes project above the rough surface. Large chondroid cells staining with alcian blue are seen there in decalcified sections. Similar domes cover the anorganic mandibular condyle of the adult rat; they may be incompletely mineralized, but mature, chondrocyte lacunae.

The sides of the shaft (Figs. 1, 3 and 5) exhibit mostly resting bone with unfinished osteocyte lacunae, a discernible pattern of collagen fibrils, and some darker, amorphous areas (Fig. 5). The base (Fig. 6) has more and larger vascular canals pene-

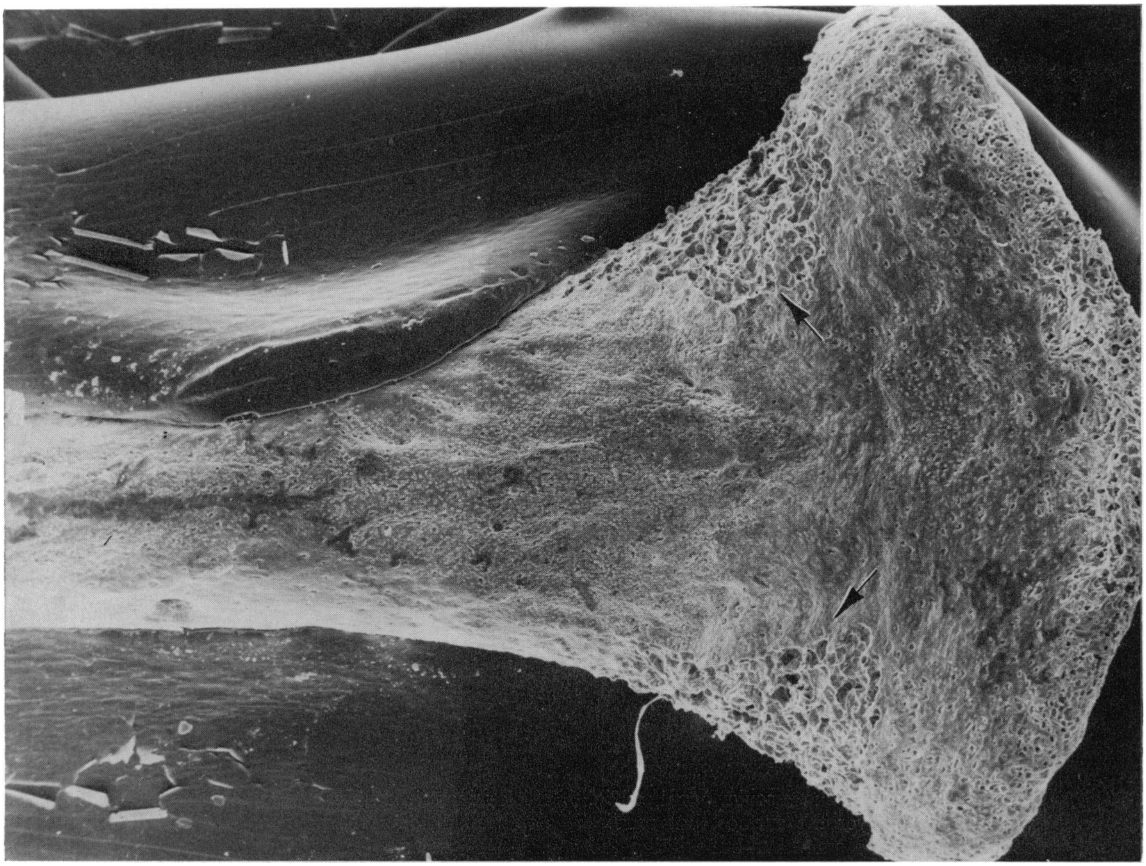

Fig. 8. Ventral view of an 8 weeks' bone showing resorption (arrowed) laterally where the shaft flares into the base. The remaining ventral surface is forming, mostly Sharpey-fibre, bone, with occasional, darker, amorphous patches. × 60.

trating it than has the shaft. A lip runs around the base, dipping down, saddle-like, into a slight, dorsal, midline depression (Figs. 5 and 6). The whole base, up to and including the lip, has a very rough texture, contrasting with smoother bone lining the vascular canals and infrequent, small, amorphous areas (Fig. 7). The surface has some osteoblast lacunae and many thick, mineralized fibres running, interwoven, irregularly over the surface, and projecting as bumps. This Sharpey-fibre bone appears to be as coarse-textured as any reported, including the dental cementum of the tapir illustrated by Boyde & Jones (1968), but is not as jagged as the mineralized fibrocartilage on the outside of the anterior process.

The external surface of the mature bone as a whole shows very little active bone formation or resorption, but the 8 weeks' bone has many resorption lacunae on the bone where the base flares out from the shaft. The resorption is on the dorsal and lateral surfaces; on the ventral surface (Fig. 8) the ring is broken by a flatter, median area of forming Sharpey-fibre bone. Figure 9 shows an 8 weeks' marrow cavity with the endosteal surface that matches the erosive, periosteal surface on the waist of the basal bulb. The several vascular canals include a larger canal starting down the shaft. The endosteal surface has the osteoblast lacunae and fine granular texture of forming primary bone (Boyde & Hobdell, 1969).

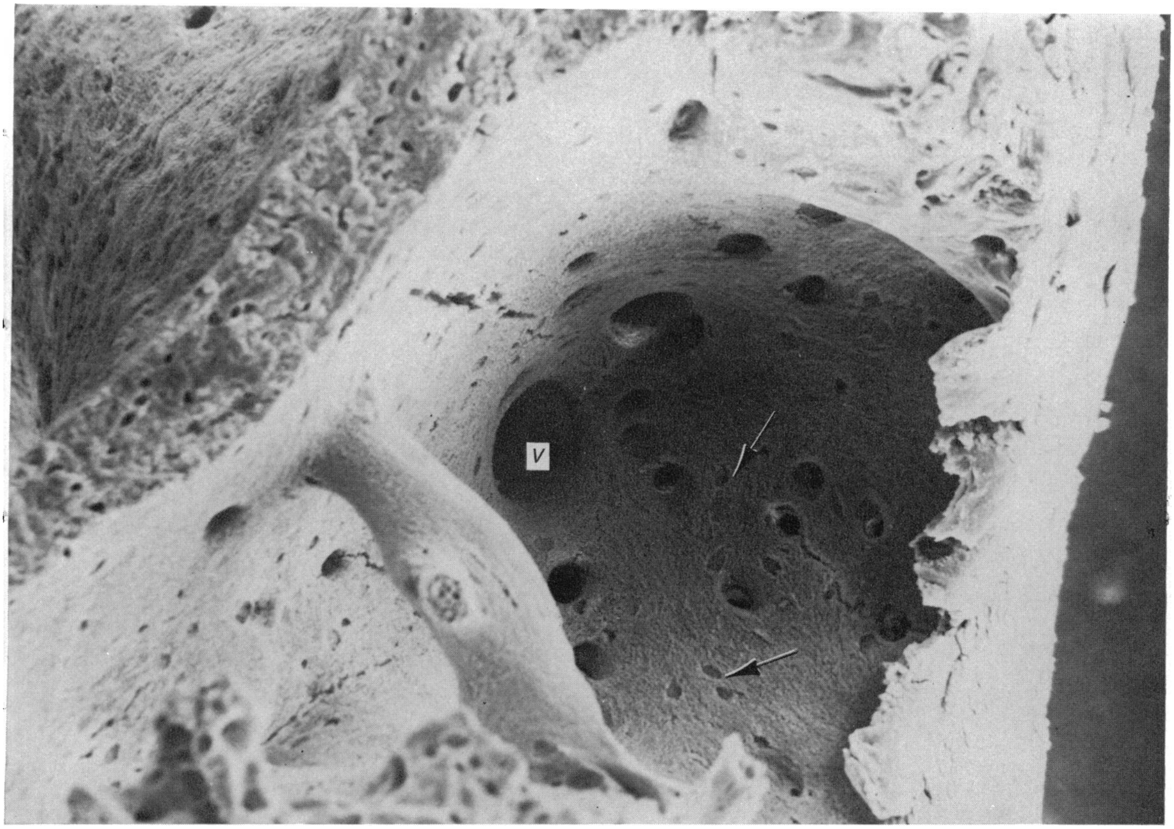

Fig. 9. View inside an 8 weeks' basal bulb showing several vascular canals, with one (*V*) appearing to enter the shaft. The fine, granular surface with osteoblast lacunae (arrow) is depository. ×180.

The basal bulb flares out like a V from the shaft, and erosion and deposition act on the V surfaces in a way that can move the growing bulb along the shaft in accordance with the V-principle noted for 'long bones' and facial bones (Enlow, 1963, 1975). Mature bones have some resorption lacunae (Fig. 10) in a similar location on the ventral surface by the flare, as in the 8 weeks' bones. In stained, decalcified sections of mature bones small flat cells and fibrous tissue lie in such lacunae, suggesting that resorption is slow or has ceased.

DISCUSSION

The radicular (cemental) surface layer of teeth is Sharpey-fibre bone (Boyde & Jones, 1968). A similar Sharpey-fibre surface covers much of the penile bone, being rougher and more complete at the base, where it attaches to the main penile erectile body (corpus fibrosum), and at the distal tip, where the partly bony anterior process fastens. The strength of the attachments is obvious when trying to separate these three, firm, penile elements.

The anterior process and tip of the bone are shaped to conform to one another in a way that, with the fibrous attachment, can be characterized as a bevelled suture. Moss (1957) showed that such sutures in the skull develop from a butt-end type as

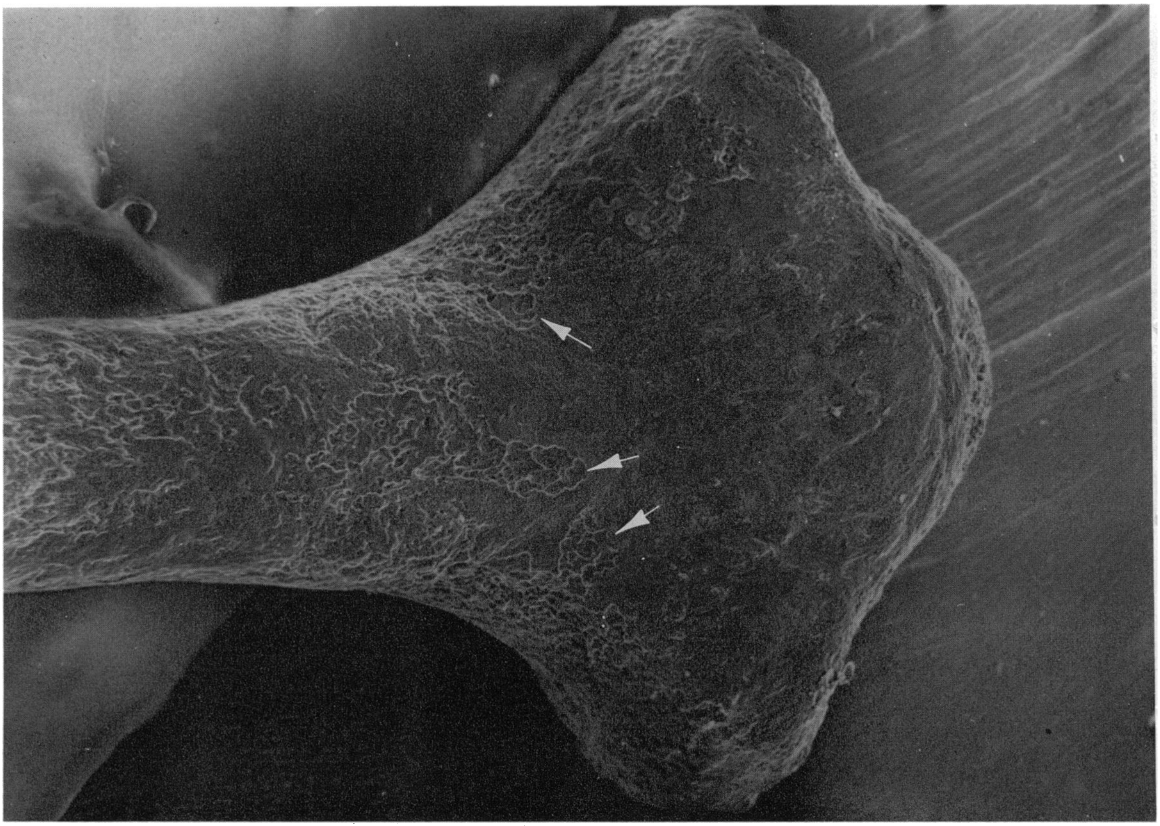

Fig. 10. Ventral view of a mature bone showing resorption lacunae (arrows) persisting in the position seen at 8 weeks (Fig. 8). × 50.

an adaptation to mechanical loading. The penile bevel appears before weaning (Fig. 2, Beresford & Clayton, 1976), and is present in these older, celibate males, so that loading by coital use is evidently not a prerequisite for this suture to develop in a bevelled manner.

Regarding the bone's function, the bevelled suture and the Sharpey-fibre attachments seem to make the corpus fibrosum, bone and anterior process into an articulating chain that could withstand and absorb major forces, e.g. at penetration, without breaking. For surgeons implanting artificial bacula into impotent men (e.g. Small, Carrion & Gordon, 1975), the rat holds the lesson that firm attachment of a baculum may be as important for coitus as its rigidity.

Scanning electron microscopy shows the penile bone to be long and straight. It grows in length by a secondary cartilage at the base, which resembles that of the mandibular condyle in having the chondrocytes arranged randomly (Beresford, 1975*a*) rather than in the columns typical of the epiphyseal growth plates of the usual 'long bone'. However, like one end of a 'long bone' (Enlow, 1965), the penile bone flares into an enlargement that changes its position relative to the shaft by a symmetrical, V-shaped pattern of remodelling. Sounder evidence that the growth of the penile bone is linear is the lining up of residual islands of spared growth cartilage matrix along the interior of the shaft (Beresford, 1975*b*). Enlow (1975) proposed that the linear orientation of the columns of proliferating epiphyseal chondrocytes contributes to the aligned longitudinal growth of 'long bones'. However, the penile bone grows long and straight from a growth cartilage of chondrocytes in apparent disarray. Whatever mechanism guides, or shapes, linear penile bone growth might also act in the epiphyses, where the chondrocytic columnar arrangement could have more to do with problems of nutrition and erosion.

SUMMARY

The penile bone and anterior process were made anorganic for scanning electron microscopy. The mature bone has a basal bulb and a long, cylindrical shaft bevelled at its tip to fit under a matching surface on the anterior process, giving rise to a bevelled 'suture'. A rough, resting, Sharpey-fibre bone surface covers the base and tip of the bone, the dorsal crest along the shaft, and parts of the lateral and ventral surfaces. The penile bone grows by endochondrial ossification at its basal end, but the cartilage cells are randomly disposed and not arranged in columns as in most 'long' bones. The growing bone, at 8 weeks, shows evidence of resorption externally where the base 'waists in' to the shaft: the corresponding endosteal surface within the basal bulb is formative, in accordance with the 'V-principle' of remodelling. It is concluded that the anterior process, penile bone and proximal erectile body (corpus cavernosum) form a firm, tightly fastened, articulating chain, perhaps serving to aid penetration.

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